TQ Objectives and Features

LARP Collaboration Meeting 4

Port Jefferson, April 6-8, 2005

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Magnet R&D FY05-FY09

	Length [m]	Aperture [mm]	FY05	FY06	FY07	FY08	FY09
Model Magnets							
Quads							
Reduced Gradient (costheta)		90		X X			
Full gradient (costheta)	1	90		X	X	X	
Large Aperture Quad	1	~120			X	X X	X
Field quality	2						X X
Full length, full gradient	4						X
Dipoles							
Open mid-plane PoP	1					X	X
Supporting R&D							
Sub-scale tests			X X	X X	X X	X X X	X X
Long coil tests					X	X	

Today's focus

Thursday's focus

Three-year Plan (LAPAC, 6/04)

The following objectives have been established for FY05-FY07:

1. **Design, fabricate and test simplified "Technology Quads"**
   - Þ **Explore different options for coil and structure**
   - Þ **Select the baseline quadrupole design**

2. Design, fabricate and test simplified "technology dipoles"

   $\Rightarrow$ Explore the feasibility of the open mid-plane approach

3. Demonstrate Nb_3Sn wind-and-react length scale-up

Technology Plan (LAPAC)

- **Fabrication and test of a simplified cos2q quad:**

  ⇒ inner or outer double-layer of a four-layer design
  ⇒ 90 mm (inner) bore for risk & cost reduction
  ⇒ joint effort LBNL+FNAL (design/fab) & BNL (test)

- Fabrication and test of one subscale model:

  ⇒ two proposals, dipole or quadrupole: discuss and select
  ⇒ joint effort LBNL (design/fab) + BNL (design/fab/test)
  ⇒ work not funded in FY05 will be considered for FY06
  ⇒ options to increase the scope at low cost (strand tests etc.)

- Conductor development

  ⇒ support TQ(4L)1a and prepare for FY06

Basic R&D Tasks (LAPAC)

- **Mechanical structures for quadrupoles and dipoles:**

  ⇒ Support Lorentz forces, deliver required pre-stress
  ⇒ Limit the stress on the conductor
  ⇒ Limit the radiation heat deposition
  ⇒ Satisfy field quality and alignment requirements

- Superconducting wires and cables (coord. w/DOE Program)

  ⇒ Electrical and mechanical stability
  ⇒ Degradation due to cabling and stress

- Length scale-up for Nb_3Sn wind-and-react technology

  ⇒ Fabrication, handling and support of long coils

Shell-based Structure

Concept:

- Aluminum shell over yoke and pads
- Assembly based on bladders and keys

Advantages:

- Can deliver very high pre-stress
- Large pre-stress increase at cool-down
- Easy assembly/disassembly/reassembly

R&D issues:

- Coil alignment, field quality
- Long vs. segmented shells

Mechanical test (FY04)

Collar-based Structure

Concept:

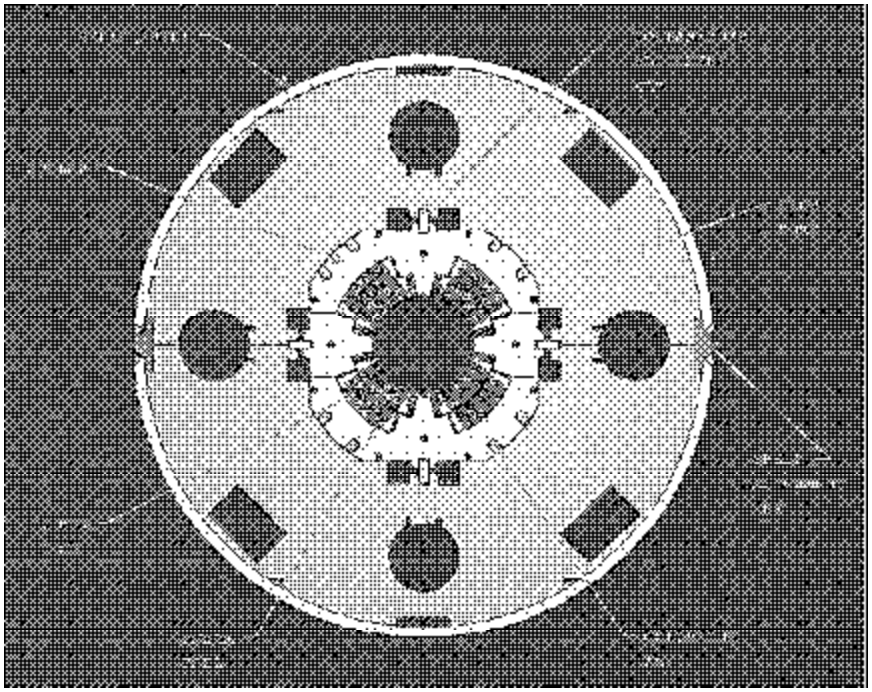
- Support by thick SS collars
- Assembly w/external press

Advantages:

- Proven coil positioning
- Proven length scale-up

R&D issues:

- Deliver required pre-stress
- Pre-stress overshoot
- Flexibility for R&D



TQ Plan for FY05(06)

Develop two short models using the same coil design and different mechanical support concepts:

- TQ1a: shell-based structure
- TQ2a: collar-based structure

Coil design:

- Simple double-layer w/conservative cable parameters
- 90 mm aperture, 1 m total length

Objectives: feedback on cable, coil and structure development

- check basic design/fabrication, *demonstrate quench performance*
- study mechanical structure, conductor, quench protection issues
- evaluate (keystoned) cable performance: stability, stress

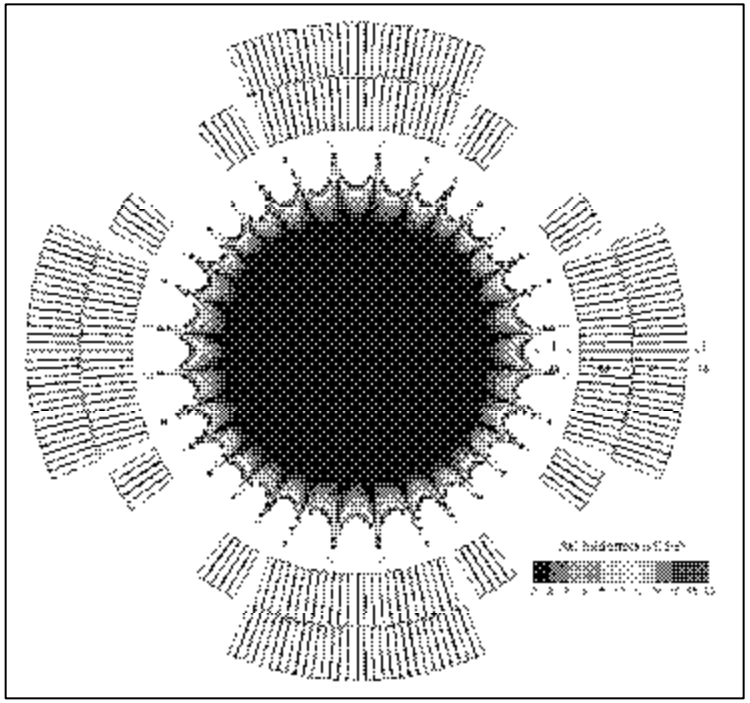
TQ1a/2a Conductor & Coil Design

Conductor:

- 0.7 mm strand **(RRP/MJR)**
- 27 **(±1)** strands
- 1.0 degrees keystone
- Width: 10.05 mm
- Mid-thickness:1.26 mm
- Insulation: S-2 glass sleeve

Coil:

- double-layer shell
- one (inner layer) wedge/octant



TQ1a/2a coil cross-section

TQ1a Milestones (Task Sheet)

Work Plan, Distribution, and Schedule:

FY05

- Design of cable, coil, and tooling:	FNAL+LBNL;	02/28/2005
- Fabricate/Insulate cable:	LBNL;	04/01/2005
- Procure coil fabrication tooling/parts:	FNAL;	04/15/2005
- Design and fabricate pad inserts	LBNL	04/31/2005
- Design and fabricate axial rods + end plates	LBNL	04/31/2005
- Fabricate practice coil:	FNAL+LBNL;	06/25/2005
- Wind/cure coils:	FNAL+LBNL;	08/25/2005
- React/impregnate coils:	LBNL;	10/15/2005

FY06

- Assemble magnet:	LBNL;	12/15/2005
- Test magnet:	BNL;	02/01/2006

TQ2a Milestones (Task Sheet)

Work Plan, Distribution, and Schedule:

FY05

- Design of cable, coil, and tooling:	FNAL+LBNL;	02/28/2005
- Fabricate insulated cable:	LBNL;	04/01/2005
- Procure coil fabrication tooling/parts:	FNAL;	04/15/2005
- Fabricate practice coil:	FNAL+LBNL;	06/25/2005
- Procure collars (modified from MQXB):	FNAL;	06/15/2005
- Assemble and test mechanical model:	FNAL;	08/15/2005
- Wind and cure coils:	FNAL;	10/25/2005

FY06

- React and impregnate coils:	FNAL;	12/25/2005
- Assemble magnet:	FNAL;	02/15/2006
- Test magnet:	BNL;	03/31/2006

TQ1a & TQ2a Budget

TQ1a	LARP		Base Program		Total
	FY05	FY06	FY05	FY06	
FNAL	236	0	0	0	236
LBNL	329	42	0	0	371
BNL	24	89	0	0	113
Total	589	131	0	0	720

TQ2a	LARP		Base Program		Total
	FY05	FY06	FY05	FY06	
FNAL	150	344	234	0	728
LBNL	36	0	0	0	36
BNL	23	89	0	0	112
Total	209	433	234	0	876

Budget Detail by Lab, FY

Date Submitted: 8 December 2004	FNAL									LBNL										BNL									
	FTE		Labor	M&S	FY04		FY05		FY06	FTE		Labor	M&S	FY04		FY05		FY06		FTE		Labor	M&S	FY05		FY06			
	P/E	D/T			Labor	M&S+G&A	Labor	M&S+G&A	Labor	M&S+G&A	P/E	D/T			Labor	M&S+G&A	Labor	M&S+G&A	Labor	M&S+G&A	P/E	D/T			Labor	M&S+G&A	Labor	M&S+G&A		
A. Shared TQ1a-TQ2a Tasks																														
A1: TQ1a+TQ2a Coils (2pr+8c+2sp)																														
Design																														
Magnetic	0.10		$ 18,000				$ 18,000			0.10		$ 18,000				$ 18,000														
Tooling (Design, M&S and Ass'y)																														
Mandrel, etc.	0.02	0.08	$ 15,600	$ 12,218	$ 15,600	$ 14,295																								
Cavity	0.04	0.130	$ 26,000	$ 6,072	$ 26,000	$ 7,104																								
Reaction	0.04	0.100	$ 22,200	$ 12,500			$ 22,200	$ 14,625																						
Potting	0.02	0.100	$ 18,600	$ 2,500			$ 18,600	$ 2,925																						
Splice	0.02	0.100	$ 18,600	$ 1,200			$ 18,600	$ 1,404																						
Ground insulation fixture	0.02	0.100	$ 18,600	$ 3,500			$ 18,600	$ 4,095																						
Parts (design and procurement)																														
Strand (return to DOE & FNAL)									$ -									$ -												
Insulation													$ 5,000				$ 5,850													
Coil (wedges, spacers)	0.02	0.17	$ 29,100	$ 64,500			$ 29,100	$ 75,465							$ -	$ -														
CTD-1008 epoxy for curing			$ -	$ 3,500			$ -	$ 4,095																						
Splices (trainer)	0.02	0.04	$ 9,600	$ 7,000			$ 9,600	$ 8,190																						
Ground insulation	0.02	0.03	$ 8,100	$ 3,400			$ 8,100	$ 3,978																						
Fabrication																														
Cable fabrication																														
Cable cleaning and insulation													0.1	$ 15,000																
Winding/curing	0.36	1	$ 214,800				$ 214,800			0.1			0.1	$ 33,000																
A2: Magnet Test																														
Test preparations																					0.1	0.1	$ 33,000	$ 14,000						
Totals (TQ1a+TQ2a coils & Test)					$ 40,800	$ 21,366	$ 357,600	$ 114,777	$ -						$ -	$ -	$ 66,000	$ 5,850	$ -	$ -			$ 33,000	$ 14,000	$ -	$ -				
Totals (Labor+M&S)						$ 62,166		$ 472,377	$ -							$ -		$ 71,850		$ -				$ 47,000		$ -				
B. TQ1a (other than coil) & MM																														
Design																														
Mechanical analysis										0.21	0.01	$ 39,363					$ 39,363													
Quench protection, etc.										0.04		$ 7,200					$ 7,200													
Assembly drawings										0.08	0.08	$ 26,400					$ 26,400													
Parts																														
Quench, heaters, and traces										0.02	0.04	$ 9,600	$ 700				$ 9,600	$ 819												
CTD-101K epoxy for impreg.												$ -	$ 5,000				$ -	$ 5,850												
Shell/yoke/pads										0.1	0.1	$ 33,000	$ 25,000		$ 33,000	$ 29,250														
Pad mods/inserts										0.02	0.02	$ 6,600	$ 4,000				$ 6,600	$ 4,680												
Z-ends, end plates										0.02	0.02	$ 6,600	$ 6,000				$ 6,600	$ 7,020												
Bladders/keys												$ -	$ 2,000				$ -	$ 2,340												
Instrumentation, connectors										0.03	0.07	$ 15,900	$ 1,500				$ 15,900	$ 1,755												
Fabrication																														
Mechanical (model) assembly										0.1	0.1	$ 33,000	$ 6,000		$ 33,000	$ 5,850														
Reaction										0.04	0.24	$ 43,200					$ 43,200													
Splicing, instrumentation										0.04	0.12	$ 25,200					$ 25,200													
Potting										0.06	0.24	$ 46,800					$ 46,800													
Sub-Assembly (parts)										0.01	0.02	$ 4,800					$ 4,800													
Shell/yoke Assembly										0.01	0.02	$ 4,800					$ 4,800													
Final Assembly (cold mass)										0.02	0.05	$ 11,100						$ 11,100												
Electricals										0.01	0.02	$ 4,800						$ 4,800												
Travelers/Procedures										0.08	0.16	$ 38,400					$ 30,000	$ 8,400												
Production reports										0.04		$ 7,200						$ 7,200												
Assembly/data analysis										0.08		$ 14,400					$ 4,000	$ 10,400												
Test																														
TQ1a test and analysis																					0.2	0.2	$ 66,000	$ 20,000						
Totals (TQ1a-specific)					$ -	$ -	$ -	$ -	$ -						$ 66,000	$ 35,100	$ 270,463	$ 22,464	$ 41,900	$ -			$ 0	$ 0	$ 66,000	$ 23,400				
Totals (Labor+M&S)						$ -		$ -	$ -							$ 101,100		$ 292,927		$ 41,900				$ 0		$ 89,400				
C. TQ2a (other than coil) & MM																														
Design																														
Mechanical analysis	0.21	0.01	$ 39,363				$ 39,363																							
Quench protection, etc.	0.04		$ 7,200				$ 7,200																							
Assembly drawings	0.08	0.08	$ 26,400						$ 26,400																					
Parts																														
Quench, heaters, and traces	0.02	0.04	$ 9,600	$ 700			$ 9,600	$ 819																						
CTD-101K epoxy for impreg.			$ -	$ 6,000			$ -	$ 7,020																						
Collar blocks, keys	0.02	0.05	$ 11,100	$ 14,000					$ 11,100	$ 16,380																				
Iron yoke	0.02	0.04	$ 9,600	$ 1,700					$ 9,600	$ 1,989																				
Skin, end plates, bullets	0.02	0.05	$ 11,100	$ 7,400					$ 11,100	$ 8,658																				
Instrumentation, connectors	0.03	0.07	$ 15,900	$ 1,500					$ 15,900	$ 1,755																				
Fabrication																														
Reaction - 3 cycles	0.04	0.24	$ 43,200				$ 14,400		$ 28,800																					
Splicing, instrumentation - 5 coils	0.04	0.12	$ 25,200				$ 8,400		$ 16,800																					
Potting - 3 cycles	0.06	0.24	$ 46,800				$ 15,600		$ 31,200																					
Mechanical model assembly	0.08	0.18	$ 41,400				$ 41,400																							
Sub-Assembly (collared coil)	0.09	0.18	$ 43,200						$ 43,200																					
Yoke Assembly	0.02	0.04	$ 9,600						$ 9,600																					
Final Assembly (cold mass)	0.09	0.18	$ 43,200						$ 43,200																					
Electricals	0.01	0.02	$ 4,800						$ 4,800																					
Misc	0.01	0.01	$ 3,300						$ 3,300																					
Travelers/Procedures	0.08	0.16	$ 38,400						$ 38,400																					
Production reports	0.04		$ 7,200						$ 7,200																					
Data analysis	0.08		$ 14,400						$ 14,400																					
Test																														
Mechanical model test	0.01042	0.010417	$ 3,438				$ 3,438																							
TQ2a test and analysis																					0.2	0.2	$ 66,000	$ 20,000						
Totals (TQ2a-specific)					$ -	$ -	$ 139,400	$ 7,839	$ 315,000	$ 28,782					$ -	$ -	$ -	$ -	$ -	$ -			$ 0	$ 0	$ 66,000	$ 23,400				
Totals (Labor+M&S)						$ -		$ 147,239		$ 343,782						$ -		$ -		$ -				$ 0		$ 89,400				
Totals (Coils+TQ1a+TQ2a)					$ 40,800	$ 21,399	$ 497,000	$ 122,616	$ 315,000	$ 28,782					$ 66,000	$ 35,100	$ 336,463	$ 28,314	$ 41,900	$ -			$ 33,000	$ 14,000	$ 132,000	$ 46,800				
Totals (Labor+M&S)						$ 62,199		$ 619,616		$ 343,782						$ 101,100		$ 364,777		$ 41,900				$ 47,001		$ 178,800				

Shared TQ1a/2a

TQ1a specific

TQ2a specific

TQ1a cost baseline

TQ1a cost baseline	FTE P/E	FTE D/T	Labor	M&S	M&S+G&A	Total
Design & Analysis						
Baseline design	0.10	0.00	$ 18,000			$ 18,000
Analysis & optimization	0.25	0.02	$ 48,000			$ 48,000
Assembly drawings	0.08	0.08	$ 26,400			$ 26,400
Tooling (Design, M&S and Ass'y)						$ -
Mandrel	0.02	0.08	$ 15,600	$ 12,218	$ 14,295	$ 29,895
Cavity	0.04	0.12	$ 25,200	$ 6,072	$ 7,104	$ 32,304
Reaction	0.04	0.10	$ 22,200	$ 12,500	$ 14,625	$ 36,825
Potting	0.02	0.10	$ 18,600	$ 2,500	$ 2,925	$ 21,525
Splice	0.02	0.10	$ 18,600	$ 1,200	$ 1,404	$ 20,004
Ground insulation fixture	0.02	0.10	$ 18,600	$ 3,500	$ 4,095	$ 22,695
Parts (design and procurement)						
Strand				$ 40,000	$ 46,800	$ 46,800
Insulation				$ 5,000	$ 5,850	$ 5,850
Coil (wedges, spacers)	0.02	0.17	$ 29,100	$ 64,500	$ 75,465	$ 104,565
Curing epoxy				$ 3,500	$ 4,095	$ 4,095
Splices	0.02	0.04	$ 9,600	$ 7,000	$ 8,190	$ 17,790
Ground insulation	0.02	0.03	$ 8,100	$ 3,400	$ 3,978	$ 12,078
Quench Heaters and traces	0.02	0.04	$ 9,600	$ 1,000	$ 1,170	$ 10,770
Impregnation epoxy				$ 5,000	$ 5,850	$ 5,850
Shell	0.02	0.04	$ 9,600	$ 8,000	$ 9,360	$ 18,960
Yoke	0.02	0.04	$ 9,600	$ 8,000	$ 9,360	$ 18,960
Pads/inserts	0.02	0.04	$ 9,600	$ 8,000	$ 9,360	$ 18,960
Z-rods, end plates	0.02	0.04	$ 9,600	$ 6,000	$ 7,020	$ 16,620
Bladders/keys	0.00	0.02	$ 3,000	$ 3,000	$ 3,510	$ 6,510
Instrumentation, drawings, connectors	0.10	0.10	$ 33,000	$ 2,000	$ 2,340	$ 35,340
Fabrication						
Cable fabrication	0.02	0.05	$ 11,100		$ -	$ 11,100
Cable cleaning and Insulation		0.05	$ 7,500		$ -	$ 7,500
Coil winding/curing	0.20	0.50	$ 111,000		$ -	$ 111,000
Mechanical model assembly/test/analysis	0.10	0.20	$ 48,000	$ 3,000	$ 3,510	$ 51,510
Reaction	0.04	0.25	$ 44,700		$ -	$ 44,700
Splicing, instrumentation	0.04	0.12	$ 25,200		$ -	$ 25,200
Potting	0.06	0.24	$ 46,800		$ -	$ 46,800
Sub-Assembly (pads)	0.01	0.02	$ 4,800		$ -	$ 4,800
Shell/yoke Assembly	0.01	0.02	$ 4,800		$ -	$ 4,800
Final Assembly (cold mass)	0.02	0.05	$ 11,100		$ -	$ 11,100
Electricals	0.01	0.02	$ 4,800		$ -	$ 4,800
Travelers/Procedures	0.08	0.16	$ 38,400		$ -	$ 38,400
Production reports	0.04	0.00	$ 7,200		$ -	$ 7,200
Assembly data analysis	0.08	0.00	$ 14,400		$ -	$ 14,400
Test						
Test preparations	0.10	0.10	$ 33,000		$ -	$ 33,000
Magnet test	0.10	0.20	$ 48,000	$ 20,000	$ 23,400	$ 71,400
Analysis and reporting	0.10	0.00	$ 18,000		$ -	$ 18,000
Total			$ 820,800		$ 263,706	**$ 1,084,506**

1,084 k$

LAPAC Closeout Comments (1)

Organization/management:

…Fermilab and LBNL have now developed parallel experiences on the manufacturing of Nb_3Sn coils and it might be worthwhile to ***compare and reconcile these experiences****, so as to develop common procedures at the two laboratories for both the subscale and the model magnet programs.*

…we have seen a good horizontal integration of effort by phases; e.g. one lab designs, one assembles, and third tests. ***Integration of effort on individual phases****, while stated to be planned, was not evident at this time. The program will benefit greatly if this was improved.*

LAPAC Closeout Comments (2)

Technical program:

…the committee concurs that it is beneficial to build identical short model magnets, rather than to investigate ***variants which may be too difficult to compare*** *and draw any relevant conclusion.*

…the 90 mm aperture seems a "conservative" and reasonable choice ***to begin with.***

…there has been progress in ***focusing efforts on fewer options*** *before proceeding with hardware tests, but in the option of the LAPAC more effort is needed in this area.*

TQ1a/2a Development Issues (1)

Adequate communication flow is required to work efficiently across labs:

- *Much improvement in the last months, but we are not quite there yet*
- *Tele/video conferences have been very useful, but limited*
- *Technical progress discussions/review in 2 weeks*

Better definition of responsibilities is also needed to improve rate of progress:

- *Example/model: cable development & fabrication*
- *Materials experts provide data and advice*
- *Task leaders are responsible to take decisions and meet schedule*
- *Should be addressed at collaboration meeting*

Implications of the use of different conductors for TQ1a and TQ2a:

- *Behaviour may differ with respect to stability*
- *Target gradients/field/stress may be different*
- *Address at progress review meeting*

TQ1a/2a Development Issues

Implications of different pre-load strategies for TQ1a and TQ2a:

- *Goal: compare mechanical structures, not coil support philosophies*
- *Address at progress review meeting*

Specifics of coil fabrication procedures and tooling need further discussion

- *Will be discussed at progress review meeting*
- *Further opportunities during practice coil fabrication*

Transfer of tooling across labs for coil reaction/impregnation:

- *Implications on schedule have not been looked at in detail*

Test planning & preparations

- *Will be addressed by integration group*

Summary

- The TQ program has developed in a way consistent with LAPAC
- All three labs provide essential contributions
- Converged on the same coil design for both models
- No significant cost overruns so far
- Good progress on design and procurements

- Several issues need to be addressed in order to:
  - maintain/improve rate of progress
  - make sure we address the final objectives

Rate of progress and successful completion of TQ1a and TQ2a are essential benchmarks towards meeting the FY09 targets